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REGIONAL AIR POLLUTION STUDY POINT SOURCE METHODOLOGY AND INVENTORY

Fred E. Littman

Rockwell International Corporation

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SMSA Emission Inventory Point Sources Pollutants SCC AQCR	PRICES SUBJECT TO CHANGE	

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RAPS POINT SOURCE EMISSION INVENTORY METHODOLOGY

1. Introduction

An emission inventory constitutes the starting point for any attempt to control emissions to the atmosphere. As long as such controls deal with average yearly concentrations, inventories giving total annual emissions of the various sources of pollutants are sufficient. The Regional Air Pollution Study has, however, as its first goal the validation of atmospheric dispersion models, which attempt to predict ambient pollutant concentrations on an hourly basis. Therefore, emission values derived from total annual emissions are largely inadequate, and the RAPS emission inventory was conceived to provide the needed time resolution and accuracy by measuring and recording hourly emissions (or parameters directly related to hourly emissions) and/or individualized hourly estimates derived for the principal sources of pollution. Thus, the emission inventory for the Regional Air Pollution Study (RAPS) at St. Louis is distinguished from existing emission inventories by two factors: its time and space resolution and its accuracy.

Although ultimately such an inventory should include all pollutants of importance, as a matter of priority, emphasis of the data collection will be placed on the two major pollutants of prime importance for modeling purposes, SO_2 as an indicator of pollution originating from stationary sources, and CO for mobile sources. Hourly measurement and estimates would provide the needed time resolution and, at the same time, increase the accuracy of the emission inventory by updating it. Later, the inventory can be expanded to include hydrocarbons (or organics), oxides of nitrogen, particulate matter, heat emissions and others.

Any attempt to obtain measured values for a large number of sources is a complex and expensive undertaking. Within the usual constraints of air pollution studies, such an approach is not feasible, and the use of algorithms or models has been generally resorted to for estimation of emissions. Since such emission models again describe assumed conditions, their use in the RAPS is less desirable and they will be used only where it does not impair the overall accuracy of the inventory, as indicated by a sensitivity analysis.

This report proposes an approach to the problem of assembling a "precision" inventory for the St. Louis Interstate Air Quality Region. It states the nature of the problem and the rationale for choosing the St. Louis area as a "test chamber"; the pollutants of interest are also discussed briefly. Using an approach suggested by NADB's Weighted Sensitivity Analysis Program, limits were placed on the scope of the investigation, which were then applied to the actual situation in St. Louis. The mechanism for the acquisition of data and their preparation prior to entry into a data bank, as well as a time schedule to accomplish these aims, are also described.

II. The Saint Louis Interstate Air Quality Control Region (SLIAQCR)

The St. Louis area was selected on the basis of careful considerations of the various factors of importance for a regional air pollution study[1]. Standard Metropolitan Statistical Areas (SMSA's) were used as a basis for the analysis, and all SMSA's with population in excess of 400,000 were examined. The primary factors considered in the selection were:

- Geographic isolation from other SMSA's
- Location within the Continental climate zone
- Significant level and density of pollutant emissions
- Presence of a rural fringe with substantial crop lands
- Existence of control programs and historical data

The final selection of St. Louis was made by the Assistant Administrator for Research and Monitoring, EPA, from the four considered sites on the basis of the following rating (Table 1):

TABLE 1

QUALIFICATIONS OF SELECTED SMSA'S

Criterion	Birmingham	Cincinnati	Pittsburgh	St. Louis
Surrounding area	Fair	Poor	Good	Good
Heterogeneous emissions	Fair	Fair	Fair	Good
Area size	Good	Good	Good	Good
Control program	Poor	Good	Good	Good
Information	Poor	Good	Fair	Good
Climate	Good	Fair	Fair	Good

(1) For details, see: Regional Air Pollution Study - A Prospectus, Part III, Research Facility, Standford Research Institute, 1972, Contract No. EPA 68-02-0207.

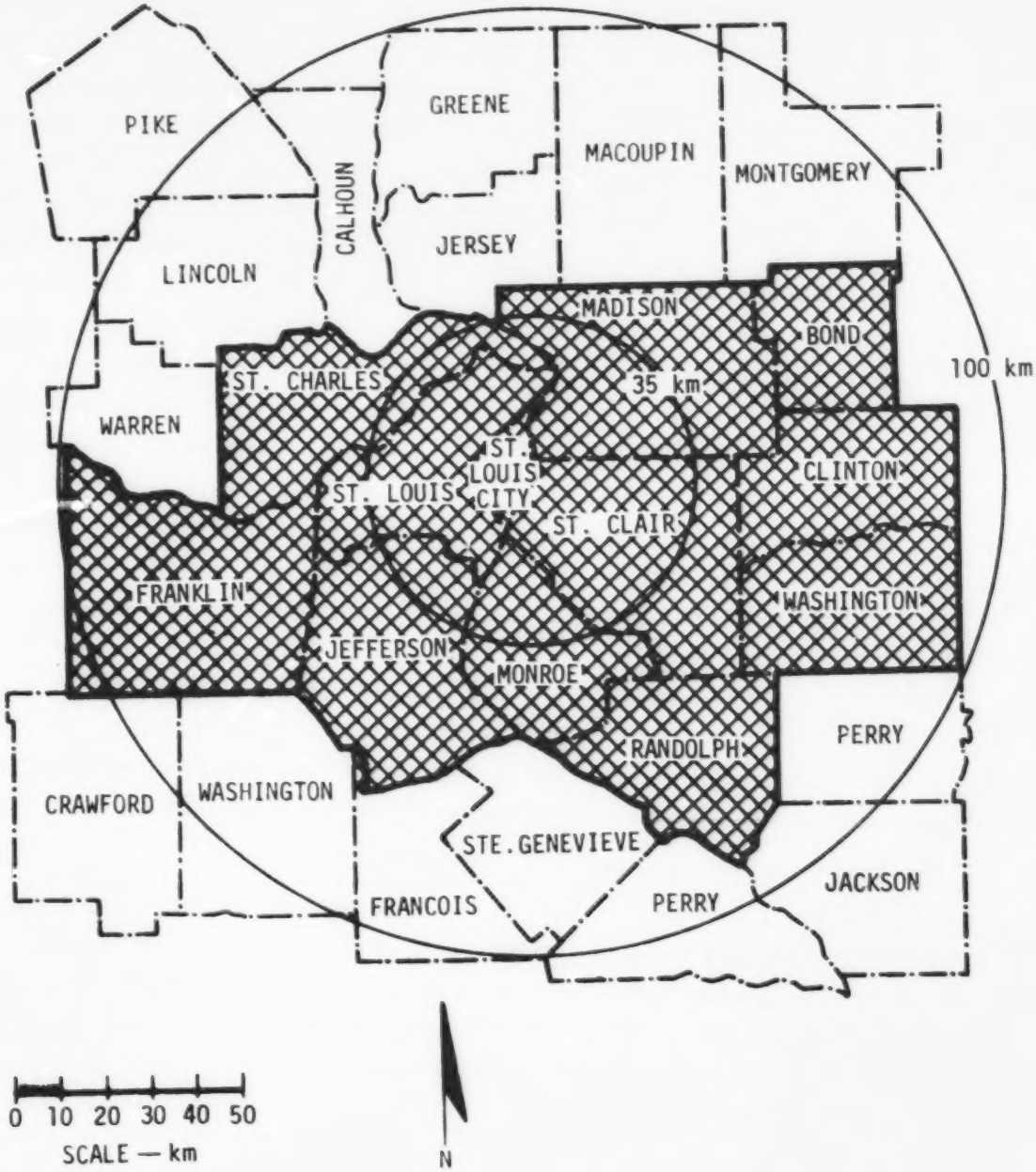

FIGURE 1 METROPOLITAN SAINT LOUIS INTERSTATE AIR QUALITY CONTROL REGION
(SHADED AREAS ARE INCLUDED IN THE AQCR)

III. Sources of Air Pollution

A. Classification

Virtually every human activity results in some form and degree of air pollution. For practical purposes, it is convenient to classify the sources of emission; a general classification in shown in Table II. There, sources are divided into stationary and mobile, since these present significantly different problems. Stationary sources are further divided into Point and Area sources. The division between the two is arbitrary: sources tested individually become "Point Sources". For the RAPS inventory, sources emitting less than ten tons of pollutants per year will not be considered, at **least initially**, as individual points but rather assigned to and distributed over the appropriate area. Of course, even a very small point source can be a major contributor to a given local or nearby receptor (monitoring station), but the investigation of this problem constitutes a localized, special situation which needs to be dealt with separately from the overall inventory. Probably the only way the existence of a local interference can be determined is by examination of the records of each station.

The division of sources into combustion and non-combustion is again a matter of convenience; however, combustion sources constitute a specific group of emitters which, in some cases, like SO_2 for stationary sources or CO for mobile sources, constitute the overwhelming fraction of these pollutants.

B. Pollutants of Interest

The RAPS inventory is, initially, emphasizing "criteria" pollutants (for which Air Quality Standards exist) and, of those, primarily SO_2 and CO, since these are the ones which will be used at highest priority in the model validation studies. An attempt will also be made to inventory heat emissions. Ultimately the inventory will also include lesser pollutants such as trace and hazardous contaminants.

B.1 Sulfur Dioxide

Sulfur dioxide (SO_2) will be the pollutant initially emphasized in the inventory since it occupies the position of highest priority within the Regional Air Pollution Study. In St. Louis, virtually all of it (98.9%) is estimated to originate from listed point sources[2]. Most of the SO_2 is produced by the combustion of coal and fuel oil, which average 3% and 1.5 - 2.5% of sulfur respectively, although some of it results from ore roasting, steel production, and

(2) Source: NEDS Inventory (1973)

TABLE II

CLASSIFICATION OF SOURCES FOR EMISSION INVENTORY

Source Category	Stationary Sources				Mobile Sources	
Source Subcategory	Area Sources		Point Sources		Area and Line Sources	
Source Process	Combustion	Noncombustion	Combustion	Noncombustion	Combustion	Noncombustion
Source units	Commercial Institutional Residential Small industrial Fuel Use Space heaters Water heaters Boilers Waste disposal--incinerators	Commercial Small industrial--Venting of organic vapors (dry cleaning, painting, gasoline storage and handling, food prepration)	Utilities Power plants Municipal--incinerators Industrial Boiler and power plants Indirect-fired air and process heaters Stationary internal combustion engines Stationary gas turbine engines Incinerators	Industrial Direct-fired process units All other industrial processes, material storage and handling	Surface vehicles Passenger cars Trucks and buses Commercial vehicles Railroads Vessels Off-highway vehicles and equipment Aircraft Piston engines Jet engines	Surface vehicles an aircraft Venting of fuel vapors Wear of tires and brakes
Pollutants	Gases and vapors SO_x NO_x CO Hydrocarbons and derivatives HCl HF Odors Particulates Fly ash and its specific chemical components Smoke	Gases and vapors Organic vapors (solvents, gasoline) Odors Particulates Organic aerosols Smoke	Gases and vapors SO_x NO_x CO Hydrocarbons and derivatives HCl HF Odors Particulates Fly ash and its specific chemical components Smoke	All pollutants	Gases and vapors SO_x NO_x CO Hydrocarbons and derivatives Odors Particulates Smoke Lead Oil aerosols Derivatives of fuel additives	Hydrocarbon vapors Particulates Organic Inorganic

Source: A Regional Air Pollution Study - A Prospectus, Stanford Research Institute, 1972.

petroleum refining operations. The largest contributors are the power generating stations of the utility companies. The six generating stations in the St. Louis area produce over 900,000 tons of SO_2 per year, or about 75% of all the SO_2 produced by point sources in the area.

Sulfur dioxide is relatively non-reactive in the atmosphere, at least over the time interval of a few hours, which is likely to be of interest to modelers. Removal from the atmosphere occurs by several mechanisms, some of which involve oxidation to sulfur trioxide with subsequent formation of sulfuric acid mist or sulfates by reaction with basic materials in the atmosphere (e.g., ammonia). These processes will have to be considered for long-term (24 hours or longer) modeling.

Available evidence indicates that the ratio of SO_2 to SO_3 in ambient air is between 50:1 to 100:1. Recent health data[3] indicate that (at least in the case of elderly patients with heart and lung diseases, as well as asthmatics) it is the level of suspended sulfates that correlates with adverse health effects rather than the SO_2 level. Best estimates indicate that sulfates are about an order of magnitude more irritating than SO_2. At this time, it is not clear whether sulfuric acid mist or sulfates are implicated, and the importance of atmospheric transformation products of SO_2 is not certain.

Ambient concentrations of SO_2 in the St. Louis atmosphere typically range from 20 to 40 micrograms/m^3 (annual average)[3].

B.2 Carbon Monoxide

Carbon monoxide (CO) is closely linked with automotive traffic. Stationary combustion sources normally generate only relatively minor amounts of CO. There are, however, a few important industrial sources of CO: the catalytic cracker regenerators in petroleum refineries, blast furnaces in steel mills, and certain chemical processes. And, because of the tremendous volume of stack gases generated by electric utilities, the relatively low concentrations of CO in these gases do contribute significantly to the overall CO concentration.

Carbon monoxide is chemically inert. It is removed slowly by contact with certain soil bacteria, which maintain the natural balance of CO in the air, but the rates of these processes are not significant on the time scale of interest.

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(3) Health Consequences of Sulfur Oxides: CHESS 1970-71, U. S. Environmental Protection Agency, Office of Research & Development, EPA 65011-74-004.

Carbon monoxide combines with hemoglobin 200 times more readily than oxygen; it thus prevents the blood hemoglobin from transporting oxygen from the lungs to the tissues. Exposure to low concentrations (below 100 ppm or 115 mg/m^3) causes headaches and dizziness. Its actions are most likely to affect persons living at high altitudes and people with chronic heart and lung diseases. Cigarette smokers commonly have 5 - 10% carboxy-hemoglobin, an amount that corresponds to 30 to 60 ppm of CO in ambient air (35 to 70 mg/m^3).

Ambient concentrations of CO in the downtown St. Louis area range from 15 to 35 $milligrams/m^3$[4].

B.3 Particulate Matter

The fate of particulate matter in the atmosphere is becoming a major research target. It is a particularly difficult subject because the characteristics of particles are determined only partially by their chemical composition and very largely by their size distribution. Thus haziness, by far the most obvious manifestation of air pollution, is strongly dependent on particle size. Similarly, the health effect of particulate matter is largely dependent on particle size, since only particles of a certain size range penetrate into the lungs and are retained there. The particle size of interest in these areas is of the order of less than five or six micrometers. Such particles remain afloat virtually indefinitely and, while their contribution to the total weight of particulate matter is small, their number is very large.

By contrast, the emission of particulate matter is determined on a weight basis, whether by sampling or by material balance consideration. Thus the small number of relatively large particles accounts for most of the mass of particulate emission. Since particles in excess of 10 μm settle out rather rapidly, these particles do not contribute much to the ambient concentration of particulates, nor to their health and visibility effects.

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(4) Air Quality Data - 1972 Annual Statistics, U. S. Environmental Protection Agency Office of Air Quality Planning & Standards, EPA-450/2-74-001.

Thus, a really useful inventory of particulate emissions would have to specify not only the mass but also the size distribution of particulate emission as well as their chemical composition -- a difficult and expensive task which cannot be carried out on a routine monitoring basis.

The problem is further complicated by the processes which form particulates -- mainly droplets -- in the atmosphere. The formation of SO_3 leads directly (via reaction with water vapor) to the formation of a sulfuric acid mist and to the stabilization of fog; photochemical reactions result in the polymerization of initially gaseous hydrocarbons, resulting again in particulate droplets. These products are only indirectly related to emission inventories.

B.4 Hydrocarbons

In the air pollution literature, the term "hydrocarbons" is used loosely to designate gaseous organic compounds. There are two major categories of sources of hydrocarbons in urban atmospheres: incomplete combustion and evaporation. Incomplete combustion occurs primarily in internal combustion engines (automobiles). Evaporation results from the storage and handling of solvents, petroleum products, etc. Additionally, methane is a normal constituent of the atmosphere, the result of natural decomposition processes.

Hydrocarbons participate in photochemical reactions leading to "smog", but their reactivity varies widely. It is therefore important to determine not only the amount of hydrocarbons present, but also their composition. From a practical point of view, usually only gross classification is possible on a continuous inventory basis, such as methane and non-methane hydrocarbons. Further separation into reactive hydrocarbons (olefins, diolefins, aldehydes, alcohols, etc.) and stable ones (e.g., parafins) is possible but will require an extensive sampling program. Complete analyses of samples collected in bags by means of a gas chromotograph are scheduled for samples of ambient air at St. Louis.

B.5 Oxides of Nitrogen (NO_x)

Emission inventories of nitrogen oxides constitute a special problem since these compounds -- particularly nitric oxide (NO) -- are primarily formed by nitrogen fixation during combustion operations. Their formation during combustion is a complex function of the time-temperature relationships in the combustion chamber, the amount of excess air present, and even the chamber configurations. Any nitrogen compounds present in the fuel also contribute to the

formation of nitrogen oxides. Because of this, the nitrogen oxide concentration in flue gases cannot be calculated from a theoretical basis but must be determined experimentally for, at least, each typical situation.

In addition to combustion sources, there are specific point sources emitting nitrogen oxides, usually NO_2, such as nitric acid plants. The NEDS inventory does not show any such sources in the > 100 tons/year category in the St. Louis area.

As mentioned previously, the importance of oxides of nitrogen and hydrocarbons as pollutants is primarily as participants in photochemical reactions where NO_2 acts as primary light absorber. These compounds will therefore be of importance to RAPS only if and when a study of photochemical reactions in the atmosphere is planned.

B.6 Heat Emissions

The large amounts of energy produced and consumed by a city eventually are converted into heat, resulting in a "heat island" which has an effect on atmospheric stability and thus affects modeling efforts. A heat emission inventory is required for a comprehensive understanding of this effect in much the same way as a pollutant emission inventory forms the basis for an understanding of the fate of the pollutants.

Point sources contribute significantly to the heat emission inventory, since a sizeable portion of the energy consumed is wasted as sensible heat of the stack gases. Even in highly efficient power plants, about 20 per cent of the energy consumed is wasted at the plant. In some industrial operations, such as blast furnaces, essentially all of the heat of combustion is released to the atmosphere at the plant.

Actually, in a self-contained area such as St. Louis, not only the waste heat turns up as heat emissions, but virtually all of the converted energy as well. Except for minor amounts of energy stored as chemical energy (e.g., in a primary aluminum plant) or radiated into space as visible light, all other forms of energy, whether electrical or mechanical, are converted into heat and released into the atmosphere, spread out over the inhabited area. Thus, as a first approximation, the total Btu content of the fuel used at St. Louis can be assumed to be released at either point or area sources. The amount of heat released by point sources can be calculated directly from fuel consumption and

known conversion efficiencies of the power boilers; it can be verified by stack analysis and measurement of gas volume and temperature, from which the sensible heat above ambient can be calculated.

Since fuel consumption figures will be obtained in any case, a program to calculate heat emission from point sources will be initiated. Significant point sources, defined similar to pollution point sources, will be treated individually, All other sources will be assigned to grid squares, whose total emission can be estimated, given the daily total of heating or cooling degree days, average wind speed, the day of the week and month of the year. Point sources can be classified into industrial, commercial and residential sources; power generation will be treated separately.

C. Sensitivity Analysis

An important aspect of every inventory is its accuracy. While no inventory can be better than the numbers supplied by the data acquisition process, a statistical estimate of the overall quality and probable error would help place the uncertainties on a quantitative basis.

As a first approach to this problem, the National Air Data Branch of EPA commissioned a study which produced a Weighted Sensitivity Analysis Program. While this program does not supply any estimates of the absolute accuracy, it does help evaluate the maximum permissible error of any part of the inventory, given a maximum permissible error for the whole system. In doing so, it keeps the inventory at an equivalent level of accuracy and points out areas where accuracy has to be improved to provide a desired overall accuracy. In addition, it also provides an approach to establish confidence levels for the emission inventory.

The basic theoretical development proceeds as follows[5]. The linear model:

$$Q^2\theta^2 = \sum_{k=1}^{N} Q_k^2 \ \sigma_k^2$$

where Q = total amount of pollutant emitted

$100\ \theta$ = percentage error associated with Q

Q_k = amount of pollutant emitted by subclass k

$100\ \sigma_k$ = percentage error associated with Q_k

is postulated as an appropriate model to analyze the propagation of errors through the emission inventory.

(5) See F. H. Ditto et al, Weighted Sensitivity Analysis of Emission Data, Fed. Syst. Div., IBM, EPA Contract #68-01-0398 (1973).

If each subclass contributes to the error an amount proportional to its relative physical contribution, it can be shown that

$$\sigma_k = \theta \sqrt{\frac{Q}{Q_k}}$$

The analysis demonstrates that to obtain a predetermined level of precision for a source class, not all subclasses need to be measured with the same precision; the greater the ratio of $Q:Q_k$ becomes, the greater becomes the allowable value of σ_k. Conversely, Q_k approaches the value of θ as the ratio approaches unity (Figure 2).

The authors also developed a method for predicting the confidence level for the inventory; that is, the probability that the actual overall error will not exceed θ, using Chebyshev's theorem (6). The results for selected pairs of (α and 1-c) are shown in Table III, where $\alpha = 2\theta$ and 1-c is the confidence level.

A two-step procedure thus is suggested. First, establish the overall allowable error θ, either from user's (modeler's) requirement or as a trade-off between confidence level and acceptable error interval; secondly, compute the values of σ_k for the components of interest.

Applying these considerations to our case suggests that, in the absence of any definite information about the modeler's requirements for the accuracy of emission data, a fairly stringent set of conditions would be a confidence level of 95 per cent and an acceptance interval of 10 per cent (these conditions are probably stricter than the accuracy of the emission data). This would lead to a permissible maximum error θ of 2.24%

Using the emission values in the latest NEDS inventory, as shown in Table IV, we can now calculate the allowable error for source classes of various sizes, such as 100 tons/year, 1000 tons/year, etc. For example, the allowable error for a 100 tons source of SO_2 would be

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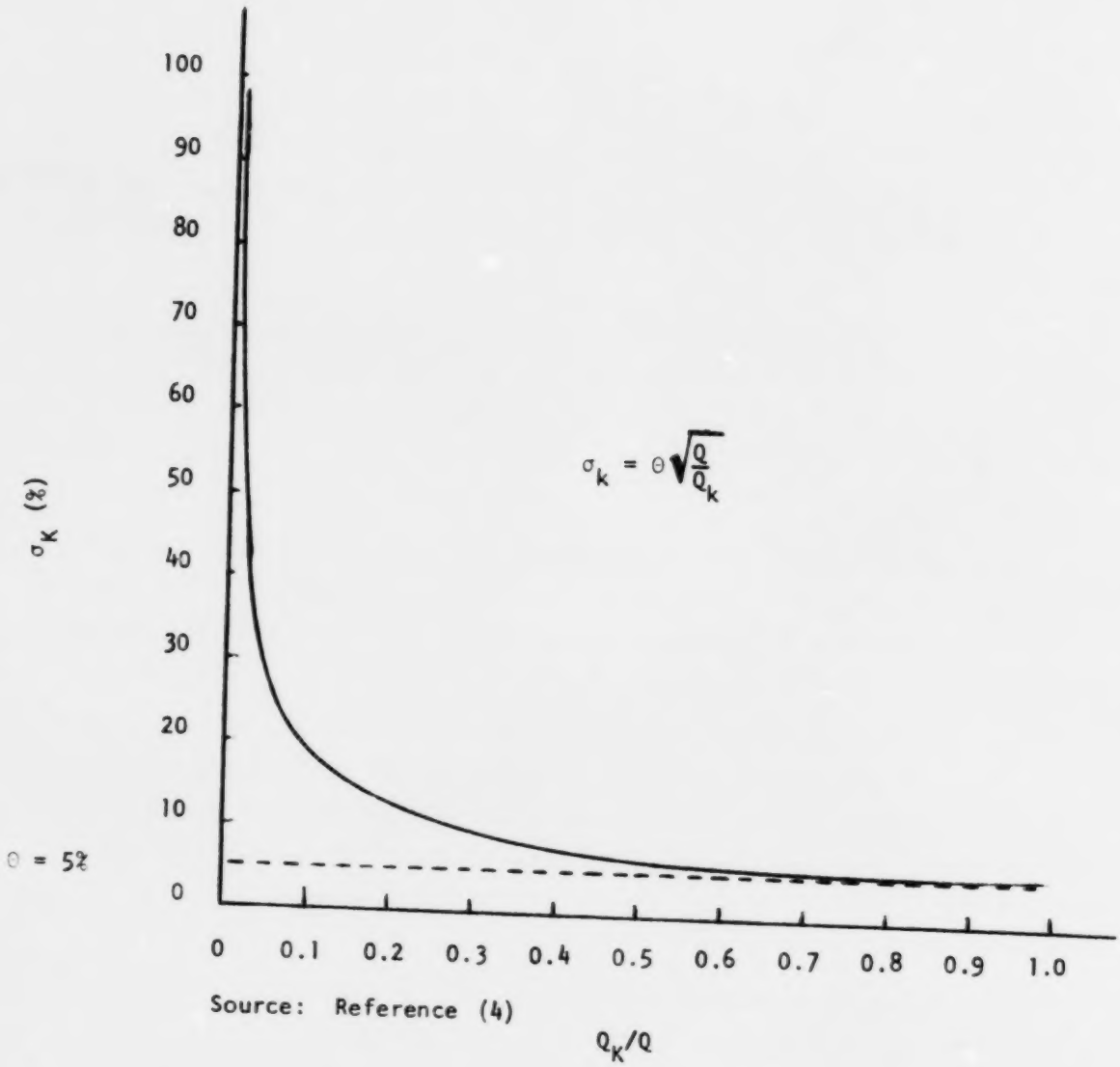
(6) Miller, I. and J. E. Freund, Probability and Statistics for Engineers Prentice-Hall, 1965.



Source: Reference (4)

RELATIONSHIP BETWEEN σ_K AND Q_K/Q

Figure 2

Confidence Level

Acceptance Interval: α \ 1-C	90%	95%	99%
5%	1.58%	1.12%	0.5%
10%	3.16%	2.24%	1.0%
20%	6.32%	4.47%	2.0%

TABLE III. VALUES OF Θ FOR SELECTED PAIRS (α, 1-C)

Source: Reference (4).

TABLE IV

POINT SOURCE EMISSION INVENTORY

NEDS, DECEMBER 1973

	STL Co.	STL City	St. Charles	Jefferson	Franklin	Wash.	St. Clair
SO_x	112,206	12,798	115,392	138,384	111,132	9	20,816
NO_x	34,979	2,647	60,086	214	28,492	5	4,069
CO	1,178	39,433	1,093	63	1,161	2	2,617
HC	9,255	15,965	328	3	303	1	4,024
Part.	12,129	6,527	321	835	1,244	900	23,623

	Randolph	Monroe	Madison	Clinton	Bond	Grand Total (Point Sources)
SO_x	473,599	--	202,630	270	--	1,187,296
NO_x	128,964	--	51,423	114	--	310,993
CO	2,993	--	2,787,726(?)	4	--	2,836,270
HC	901	--	47,694	2	--	78,476
Part.	6,399	359	271,338	277	--	323,952

NEDS, December 1973

$$\sigma_{100T} = 0 \sqrt{\frac{Q}{Q_{100T}}}$$

$$= 2.24 \sqrt{\frac{1,187.296}{100}}$$

$$= 244\%$$

The data are tabulated in Table V.

The very large σ_k for SO_2, CO and even NO_x, even for the relatively stringent statistical conditions, suggests that there is probably no need to obtain measured hourly values for 100 tons/year sources of these pollutants, since in most instances NEDS can be relied upon to provide data of this accuracy. Thus the collection of hourly data can be limited to sources of 1000 ton/year and larger. As indicated in Table III (Section C), this will reduce the number of SO_2 sources to be measured to 62, the stationary CO sources to 13, and the NO_x sources to 26. The remaining sources can then be modeled as discussed in Section IV C3.

D. Size Distribution of Sources

The situation in St. Louis lends itself to a direct attack on the problem of direct measurement of emissions because of the relatively limited number of major point sources. In terms of SO_2, the current National Emission Data System (NEDS) inventory lists about 300 sources emitting oven ten tons of SO_2 per year. Of these, only about 62 emit in excess of 1000 tons/year, an additional 120 over 100 tons/year. (Since sources emitting less than 100 ton/year are likely to contribute less than 10% of the amount specified by the National Air Quality Standards to ambient concentrations, they are usually lumped with area sources.) The 62 largest sources, representing 15 companies, are concentrated at 20 locations. Thus, the sheer physical magnitude of the problem of collecting hourly data for the major sources of pollution appears to be manageable within a reasonable budget.

The situation for other pollutants is somewhat similar. The data are summarized in Table VI.

Thus, if direct measurements of emission will be limited to sources emitting in excess of 1000 tons/year, we need to obtain data from 62 sources at 20

TABLE V

MAXIMUM ALLOWABLE ERROR σ_k FOR POINT SOURCES OF VARIOUS SIZE

ACCEPTANCE INTERVAL 10%, CONFIDENCE LEVEL 95%, θ = 2.24%

POLLUTANT	TOTAL P.S. EMISSIONS, Q TONS/YR.*	ALLOWABLE ERROR σ_k FOR POINT SOURCE OF 100 T/Yr.	1000 T/Yr.	10,000 T/Yr.
SO_2	1,187,296	244%	77%	24%
CO	1,684,794	290%	92%	29%
NO_x	310,993	125%	40%	-
HC	78,474	63%	20%	-
PART	323,952	127%	40%	-

*Source: NEDS December 1973, except for CO, which is given in NEDS at 2,836,270, apparently in error.

TABLE VI

SOURCES OF POLLUTANTS IN THE ST. LOUIS AQCR

POLLUTANT	SO_2				CO				PARTICULATE				NO_x				HYDROCARBONS			
Tons/Year	$>10^3$	$>10^2$	>10	Total	$>10^3$	$>10^2$	>10	Total	$>10^3$	$>10^2$	>10	Total	$>10^3$	$>10^2$	>10	Total	$>10^3$	$>10^2$	>10	Total
No. of Sources	62	121	121	304	13	18	62	92	28	78	165	271	26	83	256	365	23	80	165	279
No. of Locations	20	15	17	52	9	8	13	30	12	25	29	66	10	13	36	59	10	22	24	56
No. of Companies	15	11	17	43	7	4	13	24	9	25	29	63	6	10	34	50	10	19	22	51

Source: National Emission Data System, Condensed Point Source Listings, SLIAQCR, December 1973.

locations for SO_2, 13 sources at 9 locations for CO, 28 sources at 12 locations for particulates, and so on. Many of these sources overlap, thus further reducing the data collection (but not the data recording) problems. For example, of the 26 major sources of NO_x, 21 are also major emitters of SO_2. The extent of the overlap is shown in Table VII, which lists all major sources of pollutants in matrix form.

E. Existing Inventory Data

Air pollution studies have been conducted in the St. Louis area for many years, and several emission inventories have been developed. In 1964, an "Interstate Air Pollution Study, Saint Louis-East Saint Louis Metropolitan Areas" was undertaken by the U.S. Public Health Service. Questionnaires were sent out to determine fuel use and combustible waste disposal practices in the area as well as manufacturing activities. A revised emission inventory, still based on 1963 data, was published in December 1966 as Phase II of the Interstate Study.

After the Metropolitan Saint Louis Interstate Air Quality Control Region had been established, the first comprehensive inventory was taken in 1968, to serve as a basis for the Implementation Planning Program (IPP). Since then, four more inventories have been compiled:

- IBM Emission Inventory-1970
- DAQED Emission Inventory-1971
- NATO Emission Inventory-1971
- NEDS Emission Inventory-1973

In addition, the following traffic and transportation inventories exist:

- Streets and highways
- Railways and vessels

The emission inventories in current use by the Missouri and Illinois regulatory agencies were recently (Summer 1973) acquired and transferred to the NEDS files.

TABLE VII

SOURCES OF POLLUTANTS IN THE ST. LOUIS AQCR
EMITTING IN EXCESS OF 1000 TONS/YEAR

Source Name	Point No.	Pollutant					Proposed Stack Sampling
		SO_2	CO	Particulates	NO_x	HC's	
Allied Chemicals	01	x					
Alpha Cement Co.	01			x			
Alton Box Co.	01	x			x		
	02	x					
	03	x					
Amoco	01	x	x	x		x	x
	02	x					
	03	x					x
	04	x			x		x
	05					x	
	06					x	
Anheuser-Busch Co.	01	x					
Anlin Corp.	01	x					x
Chrysler Corp.	01					x	
	02					x	
Clark Oil Co.	01	x	x	x		x	
	02					x	
	03					x	
	04					x	
Columbia Quarry	01			x			
	02			x			
East St. Louis Stone	01			x			
Ford Motor Co.	01					x	
	02					x	

TABLE VII CONTINUED

Source Name	Point No.	Pollutant					Proposed Stack Sampling
		SO_2	CO	Particulates	NO_x	HC's	
GMAC	01					x	
	02					x	
	03					x	
	04					x	
Granite City Steel	01		x	x			
	02		x	x			
	03		x	x			
	04		x	x			
	05		x	x			
Highland Electric Co.	01	x				x	
Illinois Power Co.	01	x	x		x		
	02	x	x	x	x		x
	03	x			x		
	04	x			x		
	05				x		
	06				x		
	07				x		
	08	x			x		
	09	x		x	x		x
	10	x		x	x		
	11	x		x	x		
Laclede Steel	01	x			x		
	02		x				
	03		x				

TABLE VII CONTINUED

Source Name	Point No.	Pollutant					Proposed Stack Sampling
		SO_2	CO	Particulates	NO_x	HC's	
Mississippi Lime Co.	01			x			
Mississippi Portland Cement	01				x		
Monsanto Chemical Co	01	x					
	02	x		x			x
	03	x					
	04	x		x			x
	05	x		x			
	06	x		x			x
	07	x		x			
	08		x				
	09		x			x	
Municipal Incinerator	01		x				
	02		x				
NL Titanium Div.	01	x					
	02	x					x
	03	x					
	04	x					
P P G Glass	01	x					
St. Joseph Lead Co.	01	x					x
	02	x					x
Shell Oil Co.	01	x					
	02	x					
	03	x					
	04	x					
	05	x					

TABLE VII CONTINUED

Source Name	Point No.	Pollutant					Proposed Stack Sampling
		SO_2	CO	Particulates	NO_x	HC's	
Shell Oil Co.	06	x		x		x	
	07	x					
	08	x					x
	09	x					
	10	x					
	11					x	
	12					x	
Socony	01					x	
Stolle Quarry	01			x			
	02			x			
Texaco	01					x	
Union Electric	01	x			x		
	02	x			x		
	03	x		x	x		
	04	x		x	x		
	05	x			x		
	06	x			x		
	07	x			x		
	08	x			x		
	09	x		x	x		x
	10	x		x	x		x
	11	x			x		
	12	x					
	13	x					
	14	x					

TABLE VII CONTINUED

Source Name	Point No.	Pollutant					Proposed Stack Sampling
		SO_2	CO	Particulates	NO_x	HC's	
Union Electric	15	x					
	16	x					
	17	x					
TOTALS	96	62	13	26	26	23	17

These inventories are described in detail in SRI Report "A Regional Air Pollution Study Preliminary Emission Inventory" (1974) EPA No. 68-02-1026.

Most of these inventories are only of historical interest. Current data are contained in the National Emission Data System (NEDS) [7] inventory, administered by the Federal EPA, and similar inventories kept by the Illinois EPA and the Missouri agencies.

The NEDS inventory contains information on annual emissions of the five "criteria" pollutants (particulates, SO_2, NO_x, hydrocarbons [HC] and CO) from stationary point and area sources, as well as a listing of selected industrial materials emitted by chemical process, food, agriculture, chemical and mineral products industries, petrochemical operations, wood processing, and incinerators.

From the point of view of the Regional Air Pollution Study, the NEDS inventory has two major uses: it contains emission data for those sources for which detailed data are unavailable, and it provides a basis for an analysis of the problem of obtaining measured data. It therefore can serve as an interim data base for the St. Louis study until the RAPS inventory becomes operational.

IV. Emission Data Acquisition

A series of sequential steps leads to the eventual acquisition and recording of point source inventory data for the RAPS inventory. The steps are:

- Survey
- Classification of Sources into Acquisition Groups
- Acquisition of Data by:
    1) Stack analyses
    2) Fuel consumption or process data
    3) Derivation from operational data
- Transformation of Data and Entry into Computer Bank

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(7) APTD-1135, "Guide for Compiling a Comprehensive Emission Inventory", March 1973.

A. Survey

Classically, data for emission inventories are acquired by the use of questionnaires which are either mailed out or prepared by the interviewer or inspector on a one-time basis.

The requirements of the RAPS inventory for hourly measured data for a period of a year far exceed the normal reporting routine and require special arrangements with the management of the various facilities. Thus, personal contact with the appropriate corporate office by mail, phone and, ultimately, in person was considered essential to obtain the necessary cooperation. The request was made for access to data which would provide a basis for calculating hourly emissions (using OMB approved NEDS questionnaires as a starting point).

Such data could be

- stack concentration measurements
- fuel consumption records
- process data
- steam production records

These data, coupled with the necessary secondary information, such as stack gas volume, concentration of sulfur in fuel or in process materials, etc., will permit the calculation of the weight estimates of pollutant (e.g., SO_2) emitted per hour.

As a sample, appropriate officials of nine of the 15 companies emitting more than 1000 tons/year (shown in Table 2) were contacted and interviewed. These included Union Electric, Illinois Power, St. Joseph Lead, Alton Box Board, Laclede Steel, Monsanto Chemicals, Anheuser-Busch, Shell Oil Company, and Amoco Oil. These nine companies are responsible for over 90% of the total SO_2 emitted from point sources in the St. Louis area (based on NEDS data). All but two agreed to supply the necessary hourly data to RAPS; this includes the utility companies, who are emitting approximately half of all the SO_2 in the area. Thus, even if the percentage of cooperation of the smaller companies should drop off, it appears that measured data for at least 90% of the total emission of SO_2 will be available. The accuracy of these data is of the order of the finance accounting procedures used by the companies, which is higher than that of chemical analysis.

This type of a survey will be continued to include the remainder of the major sources. There are two levels at which the initial information has to be gathered:

1. Management level
2. Operational level

At the management level, an "agreement in principle" is required; usually operational personnel is present at these meetings since they will later on be involved. After an agreement is reached, the details of the data acquisition are worked out with operational personnel.

The following information is then secured from information gathered at the operating level;

1. Source Description: address, location (by UTM coordinates), type of operation (SIC and SCC Codes), etc. Most of this information is available in the NEDS printout but has to be verified (particularly location, which should be to ± 0.01 Km).
2. Needed Data: pollutant concentration in stack (rarely available), quantity and type of fuel burned, amount of steam produced, fuel analysis, process information (weight and analysis), etc. All of these data should be on an hourly basis; if they are not, the time interval should be noted, as well as time related variability.
3. Collection of Data: data collection will be arranged so as to minimize the effort required by the affected companies. A messenger circuit will be set up to pick up data once a week (or other agreed-on time interval). If required, the data may have to be reproduced; in some cases, mail arrangement will be worked out.

For point sources emitting less than 1000 tons/year, as well as those major sources where detailed data are not available, hourly emissions have to be derived by a model, as discussed further on under B3. For these sources, the following information is necessary.

1. Source description - as above.
2. Work schedule
3. Maximum process and space heating loads
4. Monthly and shift fuel weighting
5. Fuel analysis data

B. Classification of Sources into Acquisition Groups

The division of sources of pollutants into major (those emitting more than 1000 tons per year) and minor (emitting between 100 and 1000 tons/year), which is based on sensitivity analysis discussed above, produces two broad categories. Data from sources in Category I, the major sources, will be collected on an hourly basis to the extent that they are available. Data from all other sources, that is the minor ones and those of the larger ones where detailed data are not available, will be derived by a modeling or algorithmic procedures.

In Group I are the utilities and the majority of sources emitting over 1000 tons/year of pollutant, as determined by the initial survey of sources. The data available from these sources permit a direct calculation of the weight of pollutants emitted any given hour.

Although sources in Group II contribute only a minor portion of the overall pollutant load, they may be of considerable significance locally. Under certain conditions it may become necessary to obtain measured emission data from some of these sources as a special project.

C. Acquisition of Data

C1. Stack Gas Measurements

The RAPS emission inventory should ideally contain direct statements of weight of pollutants emitted from each major source as a function of location for every hour. The most direct way to acquire this information would appear to be to monitor stack emissions.

In actuality, emissions (in terms of weight of pollutant) cannot be directly measured. Stack gas analyzers only provide a measure of the concentration of the pollutant, thus requiring another measurement -- stack gas volume -- before the weight of the emitted pollutant can be determined. Stack gas volume, in turn, is not measured directly, but rather is determined by measuring the gas velocity by traversing the cross-section of the stack. From the average velocity and the known dimension of the stack, the volume of the stack gases can be calculated. In addition, the molecular weight of the sampled gas has to be determined to obtain the mass flow rate. Thus, the seemingly direct and straight-forward approach to the determination of pollutant emissions by stack analysis actually consists of a number of measurements, manipulations and calculations, each of which contributes to the accuracy of the final figure.

In the case of SO_x, there is an alternative approach since all of the sulfur is contained in the fuel and is either emitted in the stack gases or remains in the residue (ash). The distribution of SO_2:SO_3 in stack gases has been found to be about 98-99:1. Therefore, the amount of SO_2 emitted can be determined quite accurately from fuel consumption and analysis figures, and the SO_2 inventory for RAPS will be obtained in this manner. With other pollutants, there is no choice, and stack sampling is the only way to obtain the desired information.

Stack sampling methods for compliance purposes have been standardized. EPA methods are described in CFR Title 40 (Protection of Environment) as an appendix to paragraph 60.85. The methods are:

Method 1: Sample and Velocity Traverses for Stationary Sources

Method 3: Gas Analyses for CO_2, Excess Air and Dry Molecular Weight

Method 4: Determination of Moisture in Stack Gases

Method 5: Determination of Particulate Emissions from Stationary Sources

Method 6: Determination of SO_2 Emissions from Stationary Sources

Method 7: Determination of NO_x Emissions from Stationary Sources

Method 8: Determination of Sulfuric Acid Mist and SO_2 from Stationary Sources.

Method 9: Visual Determination of Opacity of Emissions from Stationary Sources.

For the purposes of the Regional Air Pollution Study, continuous instrumental monitoring would seem to be preferable to the wet chemical analyses employed by the EPA methods. A mobile van containing instrumentation for the determination of SO_2, CO, HC, NO_x and possibly particulates is expected to be used in the later stages of the emission inventory.

Stack sampling is time consuming and expensive: for this reason, it should be used only to provide a primary calibration of emission factors which are used in conjunction with more readily accessible data, such as fuel consumption or processing rates. The most extensive collection of emission factors is contained in EPA's "Compilation of Air Pollutant Emission Factors" (AP-42) which is in almost universal use. Nevertheless, emission factors contained there are averages and vary widely in accuracy. They are rated for estimated accuracy

on a scale ranging from "A" to "E", depending on the number and quality of field measurements on which they are based.

To insure the accuracy of the RAPS emission inventory, some stack testing has to be performed. Such testing should include at least one example in each SCC category; if budgetary constraints permit, a considerable number of important sources should be sampled individually, (the SRI report [8] suggests a total of 65 stack tests). Tables VIII and IX show the distribution of the major sources by SCC categories.

By combining similar sources and matching categories with actual sources in the St. Louis AQCR, the following minimum schedule (Table X) was determined if at least one installation of each type is to be represented.

The total of 19 stack tests should really be considered as a "Phase I" program, to be supplemented by furtner tests based on inspection and review of existing facilities.

As discussed above, SO_2 is the one pollutant for which adequate data can be obtained with only minimal stack testing, at least for those facilities which do not have any stack gas cleaning (scrubbing) equipment. At present, none of the boilers are equipped with such scrubbers; experimental work is being conducted with a "Catox" unit at the Wood River power plant.

Though fuel consumption and process data are potentially capable of providing quite accurate SO_2 emission figures, there is a hitch: sampling for sulfur analysis is not usually done adequately. Practices vary widely; some plants have continuous, automatic samplers, but these are located at the coal-pile end of the conveyor system. Since there are usually storage bins in the boiler-house itself, there is an 8 to 12 hour lag between the sample and the material burned. Most plants sample only intermittently -- once a shift, once a day, even once for each barge. Fortunately, the sulfur analysis of coal does seem to be fairly constant (about $\pm$ 10%). A statistical evaluation of the sampling procedures will be performed; when possible, the time lag will be incorporated in the calculations.

There is a way to get good coal samples, and that is to sample at the pulverizing mill, immediately ahead of the injection point into the furnace. If the sampling becomes a problem, it may be necessary to attempt sampling at that point.

Data for NO_x will have to be based almost wholly on stack testing. The EPA emission factors span a range of 3 to 55 pounds of NO_x per ton of coal,

(8) A Regional Air Pollution Study (RAPS), Stanford Research Institute, 1974. Preliminary Emission Inventory

TABLE VIII

DISTRIBUTION OF LARGE SOURCES IN THE ST. LOUIS AQCR BY SCC CODES

External Combustion Boilers

SCC Code	Description	Number
1-01-002-01	External Combustion Boilers, Elect. Gen., Bitum. Coal, Pulv., wet	7
02	> 100 x 10^6 Btu/hr. Pulv., dry	14
03	Cyclone	4
08	Stoked	1
1-02-002-01	External Combustion Boilers, Industrial, Bitum. Coal, Pulv., wet	1
02	> 100 x 10^6 Btu/hr. Pulv., dry	3
04	Stoked	5
09	Stoked	5
004-01	Residual Oil	4
02	Residual Oil	1

TABLE IX

DISTRIBUTION OF LARGE SOURCES IN THE ST. LOUIS AQCR BY SCC CODES

Process Heaters & Processing Emissions

SCC Code	Description			Number
3-01-023-99	Industrial Process	Chemical Mfg.	H_2SO_4-Contact	2
999-99			Miscellaneous	2
-03-010-01			Lead Smelter	1
-04-004-03		Secondary Metal	Lead Smelter	1
-06-001-03		Petroleum Ind.	Process Heater,Oil	2
001-04			,Gas	4
002-01			Fluid Crackers	4
999-98			Miscellaneous	1

TABLE X

MINIMUM TEST SCHEDULE

A. POWER GENERATION

Equipment	Fuel	Firing Mode	Minimum No. of Tests	Suggested Location
Ext. Combust. Boiler	Bitum. Coal	Stoked	2	Monsanto
" " "	" "	Pulverized	2	Wood River-Labadie
" " "	" "	Cyclone	2	Sioux-Baldwin
" " "	Oil		1	Shell Oil
			7	

B. INDUSTRIAL SOURCES

Industry	Type	Minimum No. of Tests	Suggested Location
Chemical Industry	Sulfuric Acid	1	N.L.
	Miscellaneous	2	Monsanto-Anlin
Prim. & Sec. Metals	-	2	St. Joseph
Petroleum	Heaters	2	Shell-Amoco
	Crackers	2	Shell-Amoco
	Others	1	Amoco
		10	

40 to 105 pounds of NO_x per 10^3 gallons of oil.

C2. Fuel Consumption and Process Data

From the point of view of sampling methodology, there is no real difference between emission data based on fuel consumption and data based on processing of, as an example, a sulfide ore. In both cases, the hourly weight of consumed material determines the amount of gaseous discharge. Process data are more complex, though, since the amount of residual sulfur may be more significant and variable then in the case of a simple boiler operation. Of course, if a recovery operation is part of the process (e.g., a sulfuric acid plant), then stack sampling may become the more reliable source of data. The pattern of hourly variations may still have to be determined by process data unless continuous monitors are available.

An analysis of the NEDS inventory shows that the 62 point sources emitting in excess of 1000 tons of SO_2 per year fall into the following categories (Table XI).

TABLE XI

CLASSIFICATION OF SO_2 SOURCES

SCC Code	Category	Number
1-01	Boilers, Electric Generation	27
1-02	Boilers, Industrial	19
3-05	Petroleum Processing	11
3-xx	Other Industrial	5

Thus, almost 75% (46) of the 62 sources (including all of the large ones) are boilers; another 17% are concentrated in the petroleum industry.

Carbon monoxide, another combustion-related pollutant, has quite a different distribution (Table XII).

TABLE XII

CLASSIFICATION OF CO SOURCES

SCC Code	Category	Number
1-01	Boilers, Electric Generation	1
3-01	Chemical Process	2
-03,-04	Metal. Processing	6
06	Petroleum Processing	2
5-01	Incinerators	2

Here the largest sources are metal processing (blast furnaces, etc.), petroleum processing (cat. cracking) and certain chemical processes.

Even particulate emissions are largely related to boilers; almost half of the emission sources are boilers; another 25% comes from the mineral industry (quarries, cement plants, etc.). The breakdown is shown in Table XIII. The overlap of pollutants from different sources has been indicated in Table VII.

TABLE XIII

CLASSIFICATION OF SOURCES OF PARTICULATES

SCC Code	Category	Number
1-01	Boilers, Power	13
3-03	Metal Industry	4
3-05	Mineral Industries	7
3-06	Petroleum Processing	4

TABLE XIV

CLASSIFICATION OF NO_x SOURCES

SCC Code	Category	Number
1-01	Boilers, Elect. generation	22
1-02	Boilers, Industrial	2
3-05	Industrial - Cement	1
3-06	Industrial - Petroleum	1

TABLE XV

CLASSIFICATION OF HYDROCARBON SOURCES

SCC Code	Category	Number*	
1-01	Boilers, Elect. generation	(0)	9
2-01	Internal Comb., Turbine	(0)	2
3-01	Chem. Industry	(1)	4
3-03	Primary Metals - Cooking	(1)	2
3-06	Petroleum Industry - Processing	(4)	
4-03	- Evaporation	(11)	44
4-02	Surface Coating - Evaporation	(6)	19
5-01	Municip. Incinerator	(0)	2

*Bracketed numbers are sources in excess of 1000 tons/year; unbracketed are sources greater than 100 tons/year.

The significance of the high percentage of power boilers lies in the fact that data pertaining to boiler operations are usually well kept and more readily available than data about process operations. Since SO_2 emissions can be calculated readily from fuel consumption and analysis figures, and the emissions of other pollutants are closely related to fuel consumption and operating conditions, the acquisition of hourly fuel consumption data will go a long way toward the creation of an hourly emission inventory. For this reason, considerable emphasis will be placed on the acquisition of hourly fuel consumption (and related data), particularly in the early stages of the RAPS inventory effort.

The actual data obtainable cover a wide range of formats, from computer printouts of hourly fuel consumption to strip and circular charts, and even entries in log books. As an example, the logs of the Wood River Power Station of the Illinois Power Company for 29 April 1974 are attached. Table XVI is a computer printout, giving actual weight of coal used per hour, as well as information on boiler efficiency, BTU/lb. of coal etc. for Unit 5. On the other extreme, Tables XVII and XVIII show the oil and gas usage respectively of units 1, 2, and 3. Here data are available only per eight-hour shift and consist of single meter readings.

C3. Operating Data

This group includes all those point emission sources which are either minor (emitting less than 1000 tons/year) or for which no detailed hourly data are available. Here it is necessary to fall back on the annual data recorded in the NEDS inventory or the corresponding inventory of the local enforcement agency. An approach similar to Roberts[9] will be used to approximate the emission patterns by determining the relative amounts of fuel used for space heating and for process purposes and allocating each. Space heating requirements are distributed in accordance with degree-days (deviation of mean daily temperature from 65°F in degrees) while process loads are determined from appropriate month, day and shift factors. From these data, both the sulfur and heat emissions can be calculated.

Roberts assumes that when the temperature, T, is between -10 and 55°F, there is a linear relationship for the space-heating thermal load L^S. This is expressed as

(9) For detailed description of such a system, see: Roberts, J. J., et al., Chicago Air Pollution Systems Analysis Progress, Argonne National Lab., ANL/ES-CE007.

	GENERATION			GENERATORS						TURBINES							CONDENSER						BOILER												FUEL		PURITY		
TIME	GROSS MW	NET MW	L P GEN GROSS MW	GROSS MVARS	H. P. GEN AMPS	H. P. GEN. H. PSI	L. P. GEN. MVARS	L. P. GEN. AMPS	L. P. GEN H. PSI	MAIN STM FLOW—MLB/HR	THROTTLE PRES. PSI	MAIN STEAM TEMP °F	COLD R. H. PRESS PSI	COLD R. H. TEMP °F	HOT R. H. TEMP °F	TURB. OIL FR. COOLER °F	TURB. H. R. BTU/KWH	BACK PRESSURE—"Hg	C. W. TEMP °F	C. W. (INLET) TEMP °F	C. W. (OUTLET) TEMP °F	COND. FL. TO D. A.—MLB/HR	CONDENSATE TEMP °F	FEEDWATER FLOW—MLB/HR	F. W. TO ECON TEMP °F	F. W. FR. ECON TEMP °F	ECON. GAS OUT TEMP °F	A H 1A GAS OUT TEMP °F	A H 1B GAS OUT TEMP °F	SA P D INLET TEMP °F	SB P D INLET TEMP °F	A H 1A AIR IN TEMP °F	A H 1B AIR IN TEMP °F	A H 1A AIR OUT TEMP °F	A H 1B AIR OUT TEMP °F	FLUE GAS O, %	BOILER EFFICIENCY % LO	BOILER EFFICIENCY % H.L	FUEL OIL FLOW GPH	COAL USE TONS/HR	SAT. STEAM MMHOS	COND. PUMP DISC MMHOS	PLANT H R—BTU/KWH
001	170.7	164.6	177	42	2446	26	20	2534	28	1014	1900	1015	242	650	1100	114	8592	4.0	60	35	35	527	79	951	317	538	550	270	274	66	654	143	141	508	503	0.0	87.0	91.7	0	75.2	2.3	1.7	10523
002	172.2	151.0	189	3	2375	25	- 1	2460	28	1026	1569	1031	242	622	1108	114	9073	4.0	60	35	35	961	79	968	357	533	559	271	276	66	604	142	141	505	504	0.0	87.6	91.6	0	77.0	2.4	1.7	10425
003	161.7	150.6	177	- 0	2360	25	- 4	2425	27	1012	1578	1030	243	630	1108	114	8942	4.0	62	36	36	935	84	928	358	533	559	272	275	65	604	142	139	505	505	0.0	86.5	91.6	0	75.9	2.4	1.6	10485
004	162.5	151.6	191	- 10	2371	25	- 9	2520	27	1035	1963	1027	243	679	1108	114	9131	4.0	63	35	34	953	78	949	358	534	561	272	275	65	604	142	140	507	507	0.0	88.2	91.6	0	75.9	2.5	1.9	10668
005	163.0	152.0	206	3	2451	25	- 2	2512	27	1023	1562	1027	243	676	1108	114	8962	4.0	60	35	34	937	78	933	358	534	552	271	274	65	604	142	140	506	507	0.0	87.4	91.6	0	76.5	2.5	1.9	10472
006	163.0	152.1	211	12	2350	25	6	2446	27	1037	1558	1031	242	661	1106	114	9109	4.0	60	34	34	950	78	946	357	536	560	271	275	64	604	142	140	507	508	0.0	86.8	91.7	0	77.2	2.6	1.8	10441
007	210.0	198.5	235	12	3590	25	3	3501	27	1347	1916	1043	305	695	1100	114	8743	4.0	60	38	37	1149	85	1212	440	557	625	279	285	63	604	135	133	544	544	0.0	83.7	91.5	0	99.8	3.5	1.6	10155
008	274.0	261.2	156	23	4635	25	10	4727	28	1725	1911	1028	468	706	1108	114	8460	4.0	59	40	39	1486	91	1707	458	579	669	284	291	63	604	127	123	576	579	0.0	88.2	91.3	0	130.7	4.3	1.5	9906
009	321.5	310.0	125	30	4634	25	18	4818	28	2121	1898	1044	473	708	1108	114	8721	4.0	59	39	39	1863	91	1840	459	577	671	287	295	66	604	121	115	582	583	0.0	89.1	91.1	0	142.3	5.0	1.4	9908
010	322.2	308.5	148	44	4811	25	21	4918	28	2128	1895	1038	468	704	1108	114	8742	4.0	59	39	39	1882	91	1843	458	576	660	287	296	66	604	123	121	582	583	0.0	90.1	91.0	0	141.8	5.1	1.3	10046
011	320.7	307.0	124	63	4863	25	32	4973	28	2128	1894	1031	470	702	1108	114	8818	4.0	59	40	39	1881	91	1839	458	576	663	283	290	67	604	131	130	573	575	0.0	88.8	91.1	0	142.5	5.1	1.3	10102
012	321.0	307.5	128	57	4781	25	30	4963	28	2121	1891	1031	471	704	1108	114	8808	4.0	59	40	39	1877	91	1838	459	576	664	282	288	67	604	129	126	575	576	0.0	90.8	91.3	0	141.0	5.0	1.4	10017
013	320.7	307.5	119	59	4807	25	31	4957	28	2123	1892	1034	470	704	1108	114	8814	4.0	59	40	39	1881	91	1838	459	575	664	284	291	67	604	128	125	578	576	0.0	90.3	91.2	0	141.7	5.1	1.5	10048
014	320.7	307.5	119	61	4728	25	31	4913	28	2122	1887	1034	467	700	1108	114	8732	4.0	59	40	39	1871	90	1826	458	576	664	283	290	68	604	121	120	574	576	0.0	89.0	91.2	0	141.8	5.1	1.4	10045
015	250.5	238.3	132	57	3675	25	30	3728	28	1830	1592	1042	366	700	1108	114	8532	4.0	59	37	36	1479	84	1422	434	561	617	275	280	63	604	135	133	563	564	0.0	88.8	91.4	0	113.9	4.1	1.6	10258
016	269.0	256.5	208	48	4299	25	26	4303	28	1964	1652	1028	425	672	1108	114	8882	4.0	59	39	38	1573	88	1527	449	569	645	280	287	69	604	132	130	561	562	0.0	89.3	91.5	0	121.1	4.0	1.5	10170
017	301.5	288.3	230	52	4633	25	27	4660	28	1961	1955	1043	450	701	1108	114	8763	4.0	60	40	38	1768	89	1718	455	574	658	281	288	68	604	125	122	570	572	0.0	89.5	91.1	0	136.0	4.0	1.5	10070
018	326.0	312.5	204	58	4734	25	28	4960	28	2149	1968	1026	460	697	1108	114	8706	4.0	59	40	39	1858	91	1843	460	581	672	284	290	67	604	127	124	579	580	0.0	90.0	91.2	0	142.7	4.0	1.6	9952
019	326.0	312.4	205	53	4843	25	25	4751	28	2126	1961	1028	458	694	1108	114	8705	4.0	59	40	39	1906	91	1882	457	578	672	284	291	68	604	127	124	578	580	0.0	90.5	91.2	0	143.3	3.7	1.6	10046
020	325.5	312.0	196	62	4834	25	30	4940	28	2147	1975	1039	458	707	1108	114	8721	4.0	59	40	39	1832	91	1872	461	581	676	284	291	67	604	127	124	580	582	0.0	90.2	91.2	0	142.4	3.9	1.6	9970
021	326.7	313.3	211	54	4849	25	27	4826	28	2131	1966	1041	456	711	1108	113	8739	4.0	59	40	39	1838	91	1823	461	584	682	286	292	67	604	125	122	584	586	0.0	90.2	91.1	0	142.9	3.9	1.6	9978
022	325.2	312.0	197	56	4865	25	29	4846	28	2121	1970	1029	454	700	1108	114	8683	4.0	59	40	39	1900	90	1866	458	581	674	284	291	67	604	125	123	581	584	0.0	89.3	91.1	0	142.1	3.8	1.6	9858
023	261.5	249.3	205	34	3982	25	19	3988	27	1730	1569	1028	360	677	1108	114	8897	4.0	59	36	35	1527	81	1510	420	552	608	278	285	67	604	139	136	537	538	0.0	94.3	91.4	0	111.7	3.8	1.6	10268
024	172.2	161.0	233	33	2532	25	25	2626	27	1171	2003	1041	292	681	1108	114	7883	4.0	59	39	39	1056	77	1066	398	537	559	277	286	66	604	153	152	511	506	0.0	78.0	91.7	0	82.8	2.1	1.8	10229

MEGAWATT HOURS		MILL TONS		O'H TONS	
H P GEN	85[illegible].1	SA	2		7[illegible]805
L P GEN	3155.3	SB	904		85883
GROSS	12[illegible]8.5	SC	[illegible]51		2[illegible]761
AUX.	2[illegible].1	SD	702		83[illegible]66
NET	5999.2	SE	655		36595
COAL HD	0.0	TOT	[illegible]016		

HEAT INPUT & MISCELLANEOUS	
COAL, MILLION BTU	62115
OIL, MILLION BTU	0
TOTAL, MILLION BTU	62115
COAL HEAT VALUE, BTU/LB	11030
FUEL OIL USED, GAL	0
AVG C W IN TEMP, °F	60

TERMINAL DIFFERENCE °F			
HTR A	76.1		
HTR B	27.2		
HTR C	20.0		
HTR D	16.8		
HTR F1	15.0	HTR F2	0.1
HTR G1	12.1	HTR G2	11.[illegible]

HEATER DRAIN TERM DIFF °F			
HTR A	5.8		
HTR B	3.5		
HTR C	35.3		
HTR D	9.8		
HTR F1	2.1	HTR F2	1.3
HTR G1	2.5	HTR G2	13.1

BURNER TILT TIME		
%	A	B
+30 TO +18	15	124
+18 TO 0	428	269
0 TO -18	867	373
-18 TO -30	130	63
	MINUTES	

OPERATING DATA.		
HOURS	TURB.	BLR
THIS MONTH	23	8[illegible]
THIS YEAR	7085	3[illegible]3
SINCE START	32325	3[illegible]34
GROSS MWH THIS MO		19[illegible]
AUX. MWH THIS MO		10[illegible].0

ILLINOIS POWER COMPANY
WOOD RIVER POWER STA.
HOURLY AND DAILY LOG
UNIT 5

DATE [illegible]

TABLE XVI.

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TABLE XVII

ILLINOIS POWER COMPANY
WOOD RIVER POWER STATION
BOILERS 1, 2, 3 DATA

APR 2 9 1974

DATE 4/29/74

COAL SCALE	BOILER NO. 1 COAL SCALE RDG. A	B	C	BOILER NO. 2 COAL SCALE RDG. A	B	C	BOILER NO. 3 COAL SCALE RDG. A	B	C
Shift 12 MN - 8 AM									
1. Rdg. at 8 AM									
2. Rdg. at 12 MN									
3. Difference									
Shift 8 AM - 4 PM									
4. Rdg. at 4 PM									
5. Rdg. at 8 AM									
6. Difference									
Shift 4 PM - 12MN									
7. Rdg. at 12 MN									
8. Rdg. at 4 PM									
9. Difference									
10. Total Diff. Item 7 - Item 2									
11. Total Tons Item 10/5									

	GAS Meter Reading Start	GAS Meter Reading End	FEEDWATER Meter Reading Start	FEEDWATER Meter Reading End	STEAM Meter Reading Start	STEAM Meter Reading End	STEAM Meter Difference
Shift 12 MN - 8 AM							
No. 1 Boiler	340974	340613	642710	642408	532434	532502	
No. 2 Boiler	564941	564941	561863	561863	907408	907429	
No. 3 Boiler	858225	858586	002733	003074	003704	004055	
Shift 8 AM - 4 PM							
No. 1 Boiler	340613	341032	642408	643161	532502	532768	
No. 2 Boiler	564941	564958	561863	561863	907429	907451	
No. 3 Boiler	858586	858875	003074	3494	004055	4480	
Shift 4 PM - 12 MN							
No. 1 Boiler	341032	341458	643161	643523	532768	533045	
No. 2 Boiler	564958	565240	561863	562120	907451	907702	
No. 3 Boiler	858875	858934	3494	003679	4480	004688	

	HEATING STEAM 12 MN 8 AM	8 AM 4 PM	4 PM 12 MN	BLOWDOWN UNITS 1, 2, & 3 12 MN 8 AM	8 AM 4 PM	4 PM 12 MN
Meter Reading Start						
Meter Reading End						

(7) 0.0 / (17) 2.5

1	42.5	08-24	H
2	60.0	01-24	D
3	0.0	01-24	H

Form 221-147 (12-73)

Wood River STATION Daily Summary of Operations

St | Day 6 | Month 11 | Year 74

	Start-Ups 1	2	3	4	5
12:00		19		65	160
12:30		19		57	160
1:00		19		54	160
1:30		19		55	160
2:00		19		55	162
2:30		19		53	162
3:00		19		53	162
3:30		19		53	162
4:00		19		53	162
4:30		19		53	162
5:00		19		54	162
5:30		19		54	162
6:00		19		54	162
6:30		19		61	325
7:00		19		75	320
7	12	20		98	300

Instantaneous Loads - MW

	1	2	3	4	5
8:00	22	24		100	340
8:30	34	37		102	340
9:00	40	41		102	340
9:30	40	41		102	340
10:00	41	44		102	340
10:30	41	44		102	340
11:00	40	40		102	340
11:30	34	36		102	340
12:00	35	36		102	340
12:30	15	16		102	340
1:00	14	16		102	340
1:30	14	16		102	340
2:00	14	16		97	340
2:30	14	16		97	340
3:00	14	16		96	340
3:30	15	16	21	86	270

	1	2	3	4	5
4:00	20	20	15	86	280
4:30	37	34		95	300
5:00	45	45		98	320
5:30	45	45		103	325
6:00	45	45		103	325
6:30	45	45		103	325
7:00	45	45		103	325
7:30	45	45		103	325
8:00	45	45		103	325
8:30	45	45		103	325
9:00	24	25		103	325
9:30	19	20		103	325
10:00	19	20		100	320
10:30	19	20		95	260
11:00	19	20		54	220
11:30	17	20		52	200
12:00	17	20		51	165

Fuel Usage

Coal 3,110.60 Tons | Oil #6 2 BRS. 102453 Gals | Gas NONE MCF

	Boilers 1	2	3	4	5	6	7	8	Turbines 1	2	3	4	5	Other Equipment Reducing Capability: Equipment	Time Off & On
Mark X if out of service at 12:01 AM		X	X						X		X				
Time On			7:30 AM						7:13 A		11:30 AM				
Time Off											4:13 P				
Time On															
Time Off															

Remarks (*) R.L. #02: F.O. 7'6" 1 to 4 F.O. 7'5" 1 to 4 RL. 10'
F-O 7'6 R.L. 406.7 FO 406.6
#2 - GAS

* Give brief explanation of any deviation from normal loading which is not apparent from the above listing of equipment out of service

R. W. Zillitt
Supervisor 1 AM to 8 AM

R E
Supervisor 8 AM to 4 PM

T. Nagy
Supervisor 4 PM to 12 M

TABLE XVIII.

$$L^S = L^S_{MAX} \frac{[55 - T]}{65}, \quad (-10 \leq T \leq 55).$$

Then the total thermal load is

$$L = L^S + L^P,$$

where L^P, the process load, is determined from the appropriate month, day, and shift factors. The amount of load due to coal, L^C, and due to oil, L^O, is then determined, and the SO_2 emission due to each source is calculated as follows:

$$C \text{ (tons/hr)} = \frac{L^C(\text{therms/hr}) \times 10^5(\text{Btu/therm})}{12000(\text{Btu/lb}) \times 2000(\text{lb/ton})}$$

$$SO_2^C(\text{lb/hr}) = C(\text{tons/hr}) \times 38 \times \%S^C;$$

$$O(\text{kgal/hr}) = \frac{L^O(\text{therms}) \times 10^5(\text{Btu/therm})}{18000(\text{Btu/lb}) \times 8000(\text{lb/kgal})}$$

$$SO_2^O(\text{lb/hr}) = O(\text{kgal/hr}) \times 157.0 \times \%S^O.$$

Thus, the total SO_2 emission is

$$SO_2 = SO_2^C + SO_2^O.$$

When the ambient temperature is such that a dual-fuel interruptible plant is probably receiving natural gas, the amount of SO_2 produced is correspondingly reduced.

To facilitate data storage according to a uniform and consistent format, each plant is assumed to have four stacks. For plants having less than four stacks, zeros are filled in for nonexistent stacks. The following parameters are associated with each stack:

1. SO_2 emission in pounds per hour
2. Heat emission in therms per hour.

These parameters are determined by weighting the total SO_2 and heat emissions for the plant by the percentage emitted from each stack. The heat emission, H, is assumed to be 15% of the thermal input.

V. Handling of Emission Data

As indicated in Section IV-C2, emission (or emission related) data will be provided in many different forms, ranging from computer printouts to strip or circular charts. The raw data will have to be read off the original records and tabulated in appropriate form before entry into the RAPS computer bank.

The format for the RAPS emission data storage has not yet been finalized. A data handling system (System 2000) will be used which is capable of storing data elements of variable length in repeating groups. The repeating groups define the structure for storing multiple sets of data values and link the hierarchical levels.

Data preparation forms will be designed to aid the data clerk in the structuring of the data and to make it easier to use the correct syntax. It will not be possible, however, to depend only on well-designed data preparation forms for data quality because the content as well as the form of the data must be verified.

Data verification can be carried out in part by the data management system, probably using a preliminary storage file which can be verified, proofread and corrected before the data manager decides that it is accurate enough to merge into the main file.

A detailed instruction sheet has to be prepared for each data sheet for the guidance of the data clerk. This sheet has to stipulate the units (if not indicated on the original record) and specify the manipulations, if any, which have to be performed to obtain hourly data which can be fed into the computerized RAPS inventory. In order to avoid human error as far as possible, only a minimum of handling will be carried out. For example, data will be recorded in whatever unit it is supplied and the units made part of the record. Transformation into standardized units can then be performed by the retrieval program to meet the specific needs of the user.

For most actual sources, the values stored will be consumption or other source data, rather than measured values of emission. The format will accommodate emission or consumption data. For those sources for which there are no direct emission data, emissions must be calculated using emission factors or models applied to the stored data. The emission inventory software system will

be capable of assessing the consumption data element, refer to the appropriate code, look up the emission factor of model, and compute the emission values for each specified set of pollutants.

VI. RAPS Inventory Acquisition Schedule

The acquisition of the RAPS emission inventory comprises the following elements: 1) Survey and arrangement for data collection from measured sources; 2) Data acquisition and processing; 3) Acquisition of data from smaller sources; 4) Source testing.

The survey of sources from which hourly data should be obtained should be accomplished in about three months; this will include detailed arrangements which will spell out:

- which sources will be observed.
- what data will be forthcoming.
- the necessary factors to transform available data into mass emission units.
- the mechanism of data collection.

During the next three-month period, data will be collected and their transformation into machine readable data accomplished. Data collection will continue for at least a year, possibly longer.

Data from lesser sources will be collected concurrently, beginning with about month 6 or 7. Appropriate algorithms will be designed to provide hourly emission values.

A source testing program will be set up (under another task order) to provide verification of the emission factors and other assumptions used in the program. This should be an on-going effort, utilizing a mobile test unit and providing calibration data on 20 to 60 sources. The more sources are tested, the more reliable the inventory will become; this effort is limited mostly by budgetary considerations. A minimum program was outlined in Section C-I (p. 27). This schedule is shown graphically in Figure 3.

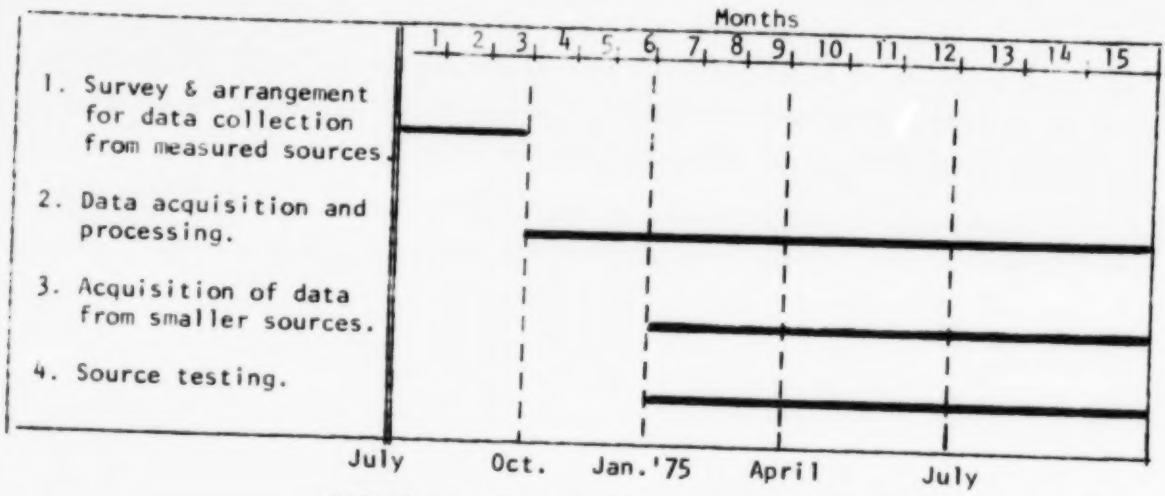
Months
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
1. Survey & arrangement for data collection from measured sources.
2. Data acquisition and processing.
3. Acquisition of data from smaller sources.
4. Source testing.
July
Oct.
Jan.'75
April
July

FIGURE 3. RAPS INVENTORY SCHEDULE

Acquisition of data (Step 2) will start about 1 October, 1974, using data obtained from Union Electric Company to check out the data entry system. By 1 November data from Illinois Power Co. will be added. Additional data, including all major sources (but limited to SO_2 only) will be included gradually. By 1 January 1975 the inventory of hourly SO_2 emissions from all major sources should be operational. Data from lesser sources will then be incorporated.

All incoming data will be entered on coding forms and visually checked for discrepancies. The tabulated data will then be transferred onto machine readable cards for delivery to NADB. Cards will be sent to NADB once a month.

VII. Summary and Conclusions

The history and purpose of the Regional Air Pollution Study in St. Louis was reviewed from the point of view of emissions of air pollutants and their inventories. Based on NEDS data on the size and distribution of the principal sources of air pollution and on a Weighted Sensitivity Analysis supplied by NADB, an emission inventory program methodology was designed to provide hourly data on criteria pollutants, with initial emphasis on sulfur dioxide. The criteria for choices were the estimated requirements of the most critical users of the data, the investigators working on dispersion model verification.

The methodology envisages a two-level approach: the measurement of hourly emissions or emission related data for the principal sources, defined as those emitting in excess of 1000 tons of pollutants per year, and a simulation of hourly emissions for smaller sources, based on yearly outputs and appropriate information on the consumption or production cycle.

The successful accomplishment of these goals should provide an emission inventory of a much higher accuracy than has heretofore been available.